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SIMULATED BALLOON FLIGHT TEST OF AN ULTRAVIOLET SPECTROMETER SYSTEM

B. A. Burch

ARO, Inc.

September 1966

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FOREWORD

The work reported herein was done at the request of Air Force Cambridge Research Laboratories (AFCRL), Air Force Systems Command (AFSC), under Program Element 62405394, Project 7621, Task 762102.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under contract AF 40(600)-1200. The tests were conducted from May 23 through 27, 1966, under ARO Project No. SR0615, and the manuscript was submitted for publication on July 29, 1966.

The major portion of the balloon spectrometer equipment was designed and fabricated by Georgia Institute of Technology (GIT), Atlanta, Georgia, under contract AF 19(628)5707 with AFCRL.

This technical report has been reviewed and is approved.

James N. McCready
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ABSTRACT

A balloon-borne spectrometer package was tested under simulated flight conditions of temperature and pressure within an environmental chamber to study the real-time pressure-temperature effects. Four components of the spectrometer package malfunctioned because of low temperature effects.

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SECTION I
INTRODUCTION

An ultraviolet spectrophotopolarimeter was designed to measure the intensity and polarization of the natural sky background to an altitude of 120,000 feet.[1] During two balloon flights of the spectrometer package, undesirable temperature-pressure effects were indicated. In order to define and eliminate these effects, the spectrometer package was tested in the Aerospace Research Chamber (ARC) (12V), Aerospace Environmental Facility (AEF), AEDC.

The complete spectrometer package was tested under simulated flight conditions of real-time variation of air temperature, pressure, and location of the sun. During the simulated ascent, malfunctions of flight hardware were experienced. Additional tests were conducted by independently varying the pressure and temperature to isolate the cause of these difficulties.

SECTION II
APPARATUS

2.1 SPECTROMETER PACKAGE

The balloon-borne ultraviolet spectrophotopolarimeter package (Fig. 1) consists of two principal elements: a sun pointer system which furnishes elevation and azimuthal stabilization with the sun as reference for the second unit, a precision spectrometer. The coarse pointing control provides the azimuth adjustment to align the yoke and fine eye block with the sun. Then the fine pointing control, with elevation and azimuth motions, aligns the fine eye block parallel to the sun rays, thus providing a stable reference for the spectrometer package.

The spectrometer is designed to measure the natural ultraviolet radiation of the sky from horizon through zenith and on to the opposite horizon. This scanning is accomplished by a programmed stepping of the spectrometer through a vertical arc which passes through the sun.

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[1]Ellis B. Hodgon and H. D. Edwards. A UV Spectrophotopolarimeter for the Study of Natural Sky Backgrounds. Georgia Institute of Technology, April 1966.

Prior to reversing direction at the horizon, motion is stopped for spectrometer calibration. The polarimeter includes a quarter-wave plate and drive mechanism which is used to measure the polarization of the incident radiation. This equipment is mounted within an open framework gondola which also contains the auxiliary apparatus, e.g., batteries, telemetry package, and control circuits. The complete flight package was tested with an auxiliary power supply substituted for the mechanical drive motor batteries.

The simulated balloon flight altitude and temperature requested by the User are shown in Figs. 2 and 3. The pressure equivalent of the geometric altitude was determined from the U. S. Standard Atmosphere, 1962.[2] The altitude tolerance was ±2000 ft, as shown in Fig. 2. The air temperature tolerance was ±10°F, as shown in Fig. 3.

2.2 AEROSPACE RESEARCH CHAMBER (12V)

The ARC (12V) (Fig. 4) is a stainless steel space simulation chamber 12 ft in diameter and 14 ft in height capable of attaining 10^{-9} torr pressure. The chamber has a complete liquid-nitrogen (LN_2)-cooled liner which provides a 77°K heat sink and a cryopump for water and carbon dioxide. The walls of the chamber contain a shielded array of 20°K gaseous-helium (GHe)- cooled cryosurfaces which will pump oxygen, nitrogen, and other 20°K condensable gases. The chamber mechanical and diffusion pumping system consists of a 750-cfm roughing pump, a 140-cfm fore pump, a 700-cfm blower, and a 50, 000-liter/sec oil diffusion pump.

A 16-channel system of tungsten filament lamps provides the radiant energy to simulate the sun or to control the temperature of the test article. An 8-ft-diam solar simulator is currently being installed on the chamber.

2.2.1 Test Configuration for Spectrometer Test

For the spectrometer test, only the mechanical pumps and LN_2-cooled liner were used since the maximum altitude to be obtained was 120, 000 ft. A temperature controlled gaseous nitrogen (GN_2) inbleed was used to help control both pressure and temperature during the simulated trajectory. Four tungsten filament lamps were used to control

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[2] U. S. Government Printing Office, Washington, D. C. U. S. Standard Atmosphere, 1962.

the temperature of the LN_2 liner as desired. During the test, the liner was not filled completely with LN_2; only enough LN_2 was admitted to lower the liner to the desired temperature. Thus the gas temperature and pressure in the chamber were controlled by combinations of inbleeding GN_2, LN_2 cooling of the cryoliner, regulating power to the heat flux lamps, and using various mechanical pumps.

The gas inbleed system, schematically shown in Fig. 5, supplied nitrogen at pressures from 0 to 150 psi, with flows of from 0 to 120 std cfm, and at temperatures from 70 to -70°F. The inbleed gas flow was manually regulated with a needle valve. The gas was cooled by passing it through a LN_2 heat exchanger. Bone-dry nitrogen was selected as the inbleed gas instead of atmospheric air as it was readily available and avoided condensation on the surfaces of the heat exchanger, test article, and chamber liner, as well as preventing fog in the chamber. The gas was injected into the chamber through a multi-orifice sphere, centered slightly above the test article, to ensure uniform circulation.

Two high intensity light sources were located in the chamber to serve as simulated suns or reference points. These were located 90 deg apart near the chamber walls as shown in Fig. 6. The light source comprised two 1000-w Colortran® lamps.

2.3 INSTRUMENTATION

The measurements made during the tests consisted of the pressure and the air temperature in the chamber, the temperature of various component parts, and the output from the spectrometer package. The pressures and temperatures were transmitted by hard lines to the data recording equipment, and the spectrometer package output was transmitted by coaxial cable from the telemetry transmitter to an rf wattmeter outside the chamber and from the wattmeter by coaxial cable to the data recording equipment.

The direct analog data consisted of 2 chamber pressures, 6 air temperatures, and 24 spectrometer package component temperatures. The location of the 24 thermocouples on the spectrometer package is given in Table I. The pressure transducers and air temperature probes were located as shown in Fig. 6. The pressure transducers, with ranges from 0 to 1 and 0 to 15 psia, were oriented toward the chamber center. Small wire copper-constantan thermocouples (Fig. 7) were used to obtain a rapid response from the temperature probes. The long bare leads were to ensure equilibrium with air temperature and to eliminate conduction from the support.

The radio telemetry signal consisted of seven subcarrier bands, of which six were frequency modulated (FM/FM) and one was pulse amplitude modulated (PAM). Two bands of FM/FM data were recorded on a strip chart, and the remaining data were digitized and recorded on magnetic tape.

The universal data system was used to gather, display, and reduce test data. The system can receive radio telemetry and direct analog, and is capable of handling 1000 channels of data. All inputs were periodically scanned, and the data digitized and recorded on magnetic tape. Printed tables of both raw data as received from the spectrometer package and pressure and temperature data reduced by the system computer were obtained.

Pressure and temperature data necessary for control of the chamber environment were available at the chamber by two means. One was a parallel readout of the air pressure and temperature inputs to the data system. The other was a direct readout of additional thermocouples located on the chamber liner and on the gas inbleed line.

SECTION III
PROCEDURE

3.1 GAS TEMPERATURE AND PRESSURE CONTROL

Continuous monitoring with manual regulation of internal chamber pressure and gas temperature was used to maintain the desired flight conditions. Pressure simulation was achieved by varying the rate of gas inbleed and the pumping capacity. The pump capacity required was lowest initially and was increased by changing pumps or combinations of pumps as altitude increased. Gas inbleed was used throughout most of the test to prevent temperature stratification and uneven cooling within the chamber. Gas temperature was varied by cooling or warming both chamber liner and inbleed gas. The liner was cooled by periodically admitting small amounts of LN_2, and was warmed with the heat flux lamps.

3.2 TEST PROCEDURE

Power was applied to the telemetry equipment and motors of the test article, and the operation of the complete system was checked. The chamber was closed and the desired pressure and temperature

simulation was begun. Data were periodically recorded, and continual visual observation was maintained throughout the test run. Since the pointing controls required a changing reference point to testing performance, the two light sources were operated alternately for 15-min periods.

SECTION IV
RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Simulated Balloon Flight Environment

The purpose of this test was to determine if there were any undesirable pressure-temperature effects to the spectrometer flight package. The simulated pressure and temperature are compared with the desired flight environment in Figs. 8 and 9. The gas temperature is an average value of the six thermocouples located around the flight package. The simulated flight began at an equivalent altitude of 4700 ft and 83°F with all systems operating normally. The simulated altitude was maintained within the 2000-ft tolerance. During the early part of the simulated flight the temperature deviated up to 15°F from the desired flight temperature. Although this was higher than the desired 10°F deviation, it was acceptable to the User. It was caused by the higher initial temperature. During a subsequent part of the temperature trajectory a malfunction of the test article caused a change in plans, as described later.

The first temperature-pressure effect occurred after 50 min of simulated flight when slower rotation of the quarter-wave drive and an instability of the fine pointing control were observed. At time 60 min, when the position of the light source was changed, the fine pointing control did not function in azimuth or elevation. The coarse pointing control would not index the spectrometer when the lights were switched after 81 min. In an attempt to determine the cause, the temperature profile was abandoned and warmup from -80°F was begun. The chamber conditions were -22°F and 83, 900 ft when 140 min had elapsed. The three systems were still inoperative, and the simulated flight test was terminated. The chamber was returned to ambient pressure, and once the components had warmed, all became operative.

4.1.2 Altitude Test

To define the cause of the difficulties encountered in the simulated flight test, a variable pressure and constant temperature test was

performed. The altitude test began at the initial conditions of 4700 ft and 72°F with the spectrometer package operating normally. The altitude simulated during the test is shown in Fig. 10.

The first incident occurred at 45, 000 ft when the light sources were alternated. Instead of rotating directly, the spectrometer rotated 270 deg to the alternate light source, wrapping the test thermocouple leads around the support yoke and impeding further motion. Since these leads were installed as part of the test setup, this incident was not a malfunction of the spectrometer package. The chamber was returned to ambient pressure to unwind the leads, and the altitude test was resumed.

The fine pointing control became unstable at 75, 000 ft. While maintaining this altitude, the light source was changed to the nearest source. The spectrometer indexed and then searched approximately 10 min before stabilization. This incident never re-occurred during the remaining test up to 128, 000 ft. The transmitter batteries exhausted their limited charge, and the altitude test was concluded with the spectrometer package having operated satisfactorily.

4.1.3 Temperature Test

The difficulties experienced during the simulated balloon flight appeared to be temperature dependent, and to verify this a variable temperature and constant pressure test was performed. A constant altitude of 40, 000 ft was chosen as this is the lowest elevation where minimum flight temperature occurs. The flight temperature, with intentional delays at -25 and -50°F, was simulated within 5°F as shown in Fig. 11. Auxiliary power was substituted for the expired transmitter batteries during this test.

After 26 min of testing, when the gas temperature was -20°F, it was observed that the spectrometer failed to calibrate automatically. This malfunction, not previously noticed, re-occurred throughout the remainder of this test. At this time the light sources were alternated, and the unit indexed properly. It was observed that the rotation of the quarter-wave plate drive had slowed to 20 percent of the original speed and 6 min later became erratic. This was considered a component failure. The quarter-wave plate drive temperatures during both simulated flight and temperature tests are shown in Fig. 12. Failures occurred in both tests when the component temperature went below 20°F.

When the gas temperature reached -25°F the fine pointing control would not stabilize on the far lights. The spectrometer was indexed

to the near lights and became stable. After 40 min with a gas temperature of -37°F, the fine pointing control ceased to operate. Fifteen minutes later, at -50°F the coarse pointing control operation slowed. The temperature was lowered to -60°F, and the coarse control ceased to operate. The component temperatures of the pointing control amplifier case (Fig. 13) and of the transistor heat sinks for the amplifier input stage (Fig. 14) and output stage (Fig. 15) are shown for the simulated flight and temperature tests. The amplifier case temperatures at the time of failure of the fine and coarse pointing controls were 0 and -25°F. The input stage transistors were subjected to lower temperatures than the output stage as seen by the minimum test temperatures of -30 and 0°F. Failures of the fine and coarse pointing controls occurred when the transistor heat sink temperatures of the input stages were below 10 and -10°F, respectively.

The test was concluded with a total elapsed time of 60 min.

4.2 DISCUSSION

4.2.1 Spectrometer Package

In the simulated balloon flight, malfunctions occurred in the following equipment: the fine pointing control, coarse pointing control, and the quarter-wave plate drive.

In two previous flight tests the pointing controls had not operated satisfactorily, however, the quarter-wave plate and the automatic spectrometer calibration had apparently operated satisfactorily, and these problems were not anticipated. The simulated flight test (altitude and temperature) indicated that the malfunctions were temperature induced. The spectrometer package performed satisfactorily throughout the altitude test. The repetition during the temperature tests of the malfunctions experienced in the simulated flight test verified that the problems are temperature induced.

Although no complete and detailed calculations have been made because of lack of detailed drawings, it appears that some of the problems in the drive system are caused by differential expansion of component parts. Thus the gradual slowing and stopping of the systems with decreasing temperature can be eliminated by redesign or by adding temperature control to those parts.

The component temperature and telemetry data should be helpful in locating and eliminating the cause of the control malfunctions. These

component temperatures could be used in additional tests on the components which failed. Selection of parts which will withstand the lower temperature or supplying heat to critical components are two possibilities to be considered in eliminating the temperature problems.

4.2.2 Chamber Operation

The high altitude environmental chamber was successfully adapted with minor additions to simulate the slowly changing pressure and temperature of the balloon flights.

SECTION V
CONCLUSIONS

The spectrometer package experienced several malfunctions during the simulated flight conditions of balloon ascent.

The spectrometer package performed satisfactorily throughout the entire altitude range; however, several components became inoperative during the variable temperature test. Malfunctions of the following spectrometer package equipment were caused by low temperatures experienced during the simulated balloon flight: the fine and coarse pointing controls, the quarter-wave plate drive, and the automatic spectrometer calibration. Using the results of the test, suitable changes or redesign can be accomplished to overcome the problems encountered.

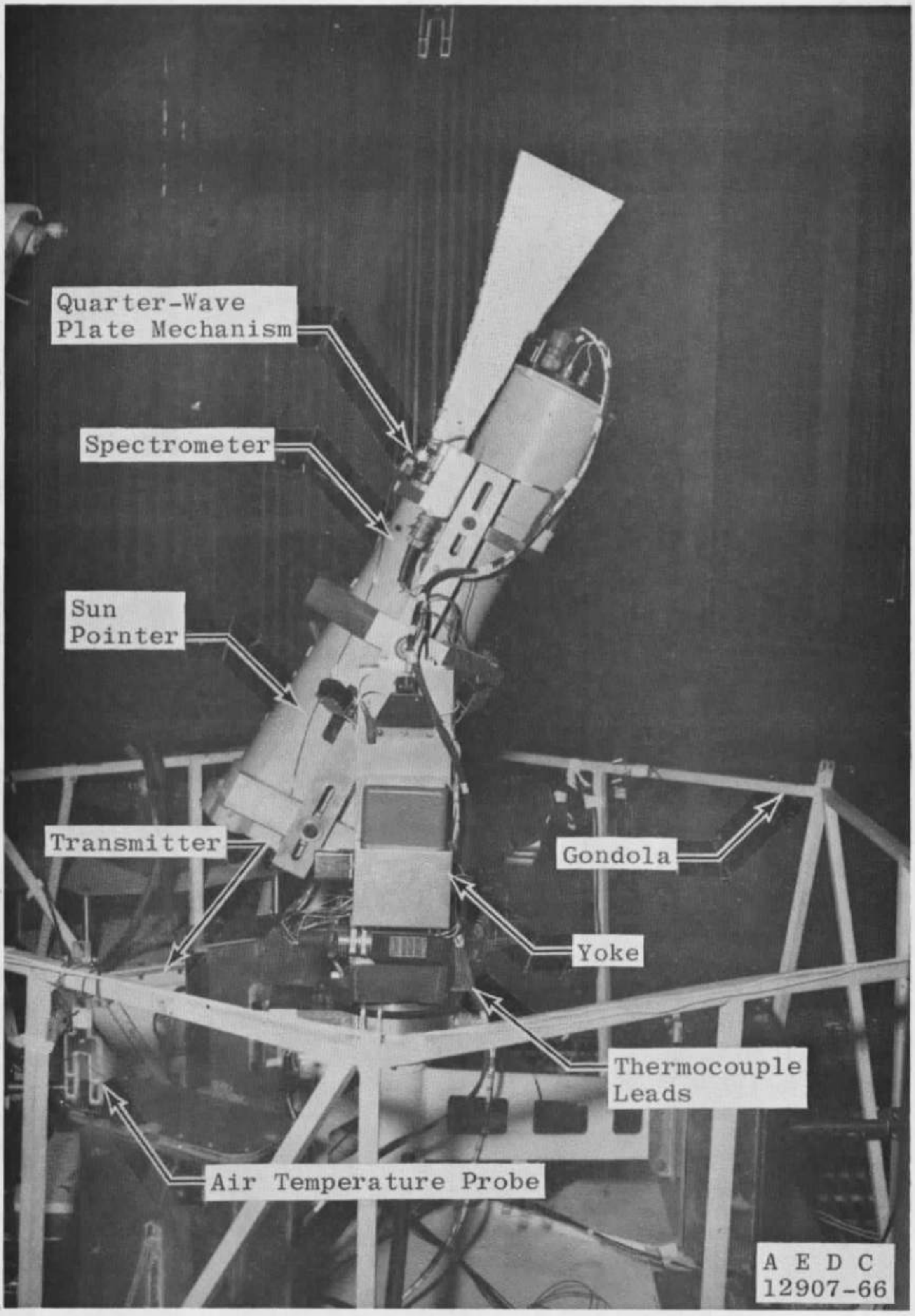


Fig. 1 Balloon Instrument Package

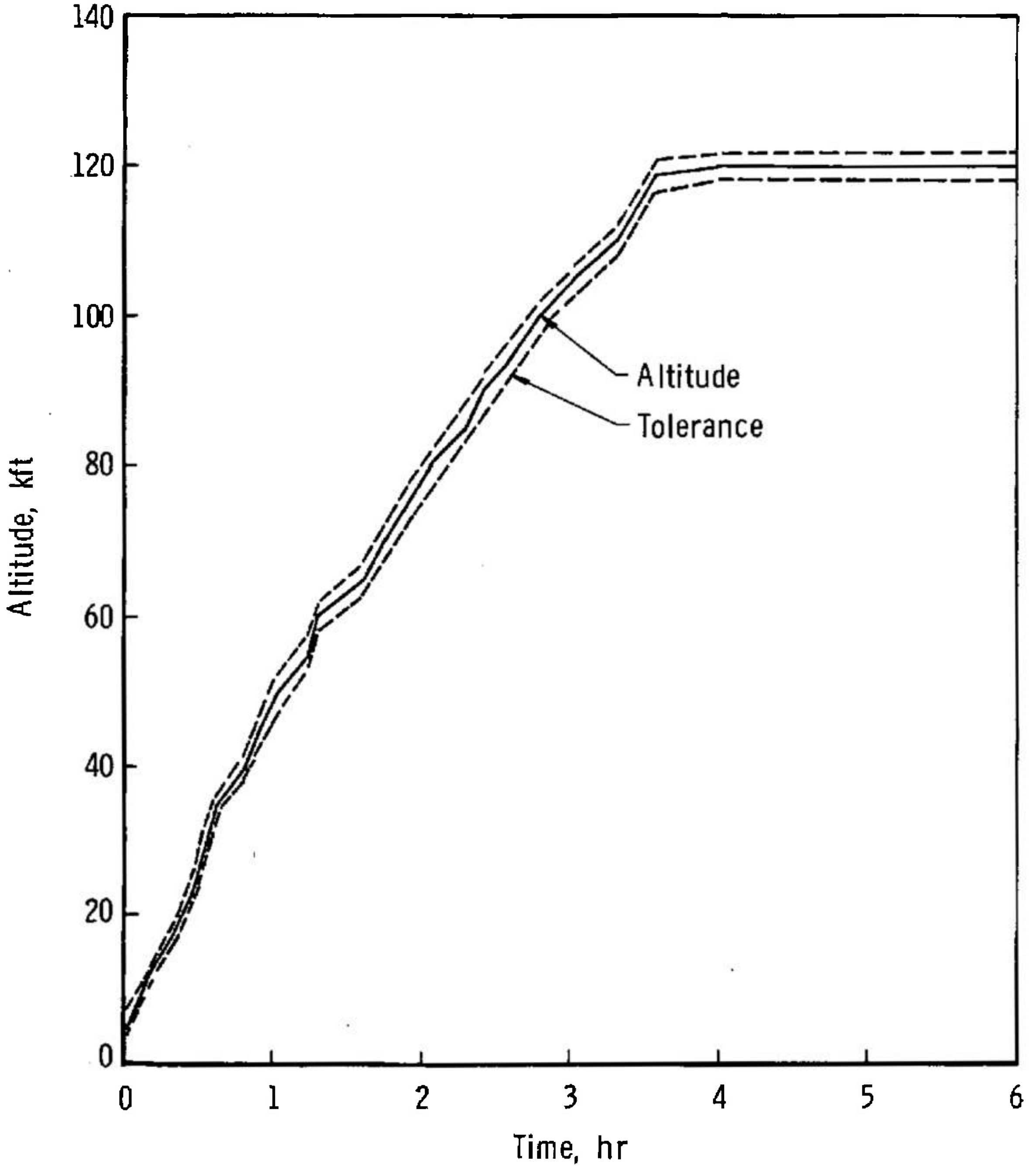


Fig. 2 Balloon Flight Altitude

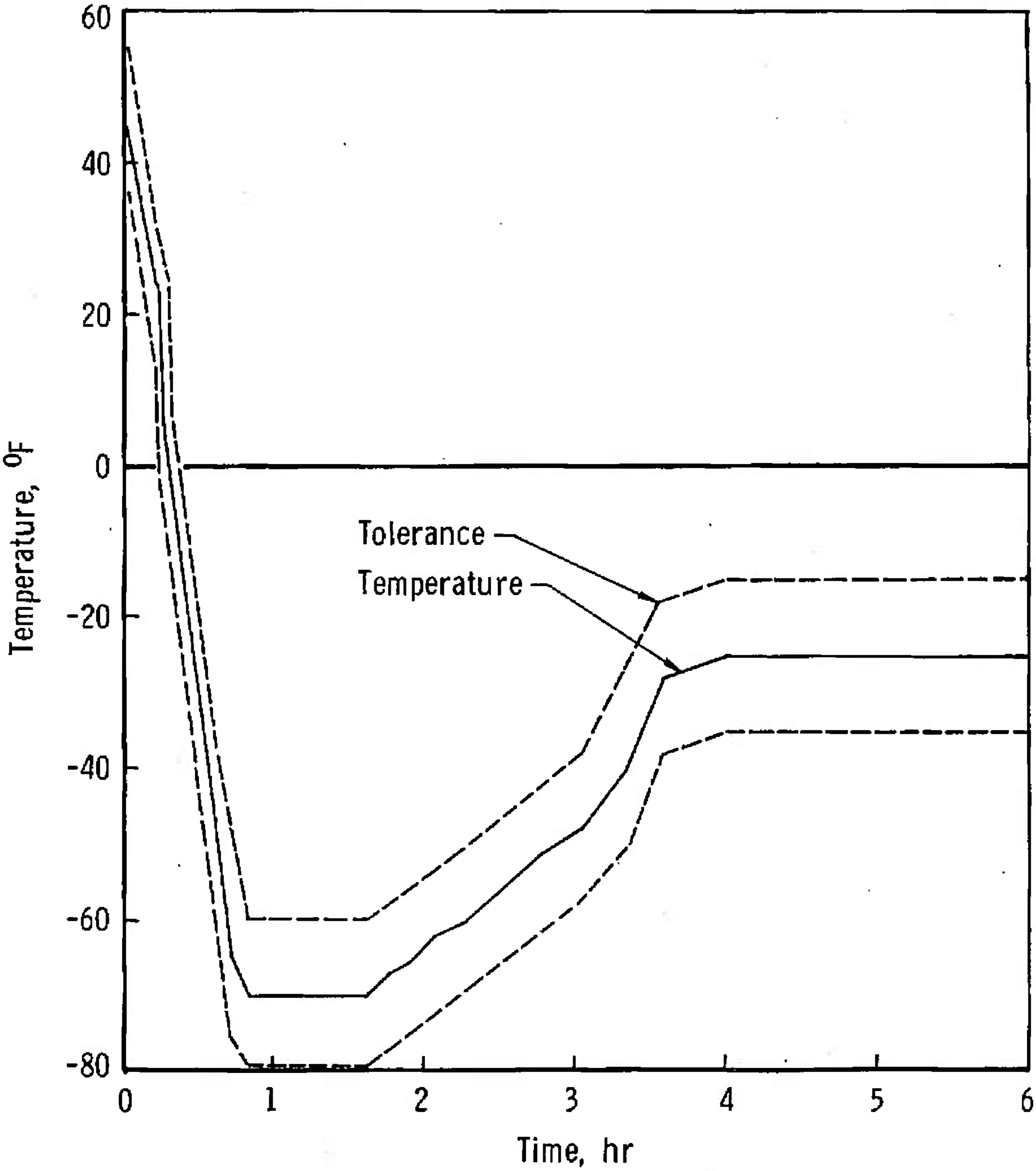


Fig. 3 Balloon Flight Temperature

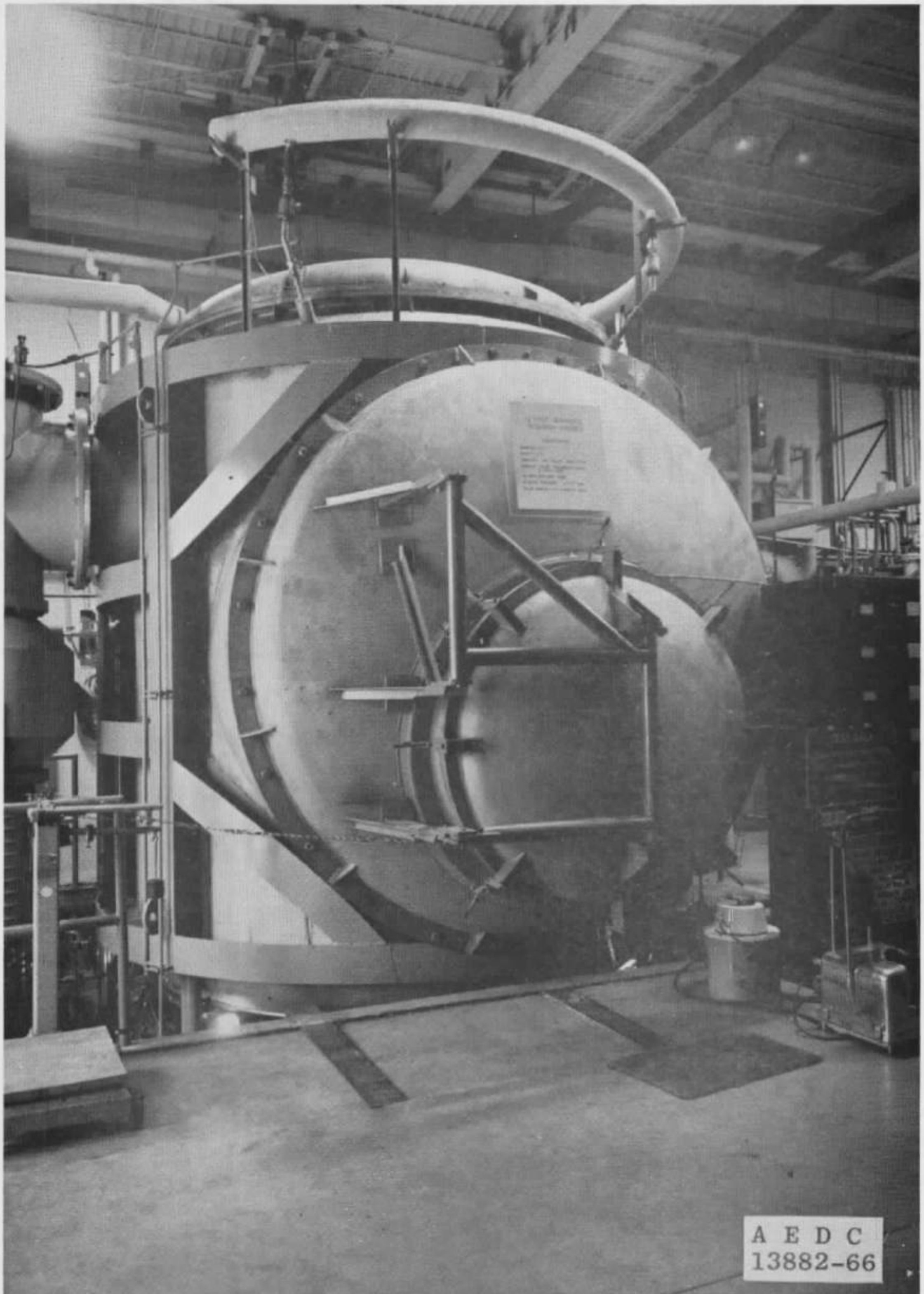


Fig. 4 Aeraspace Research Chamber (12V)

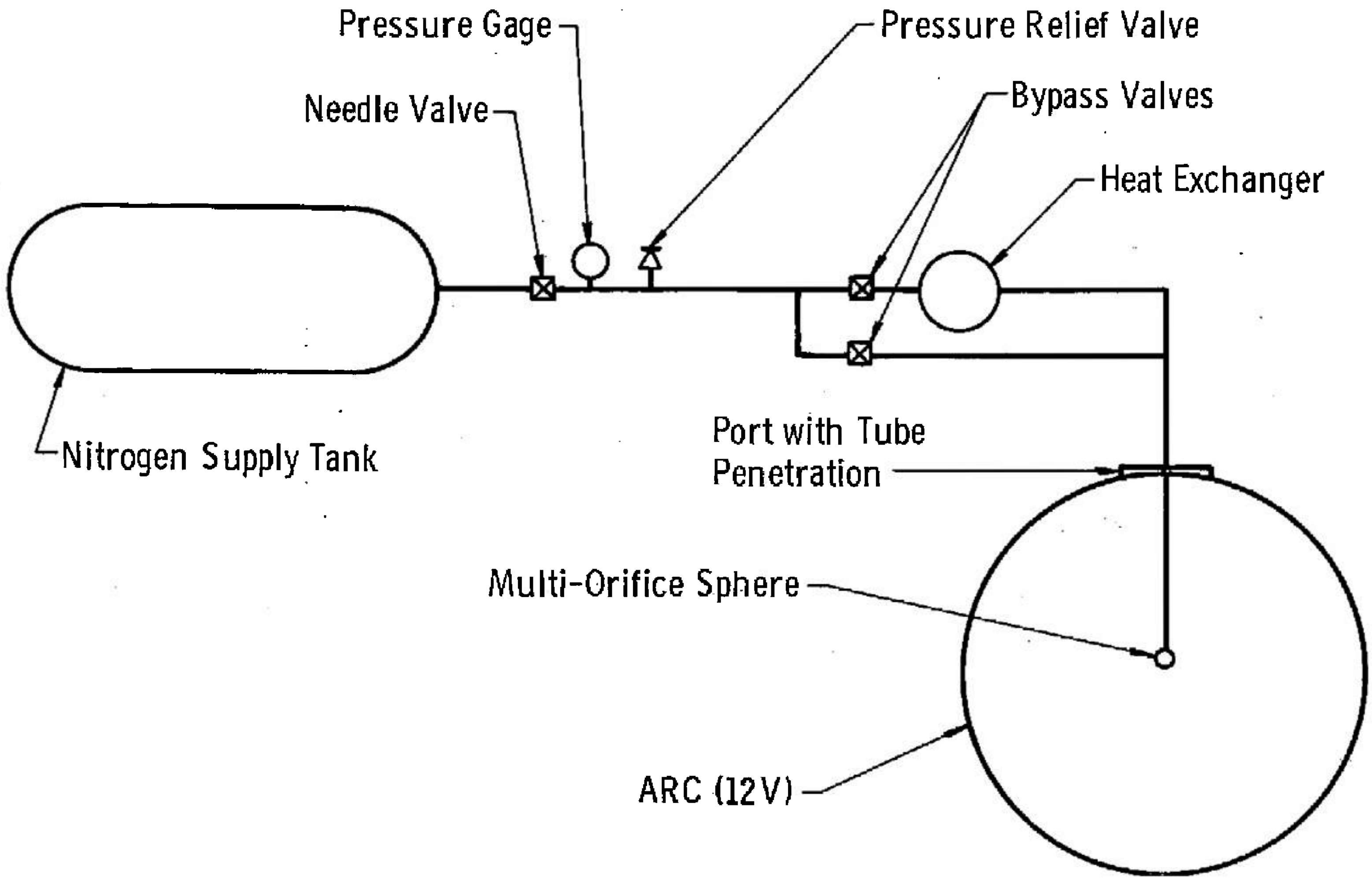
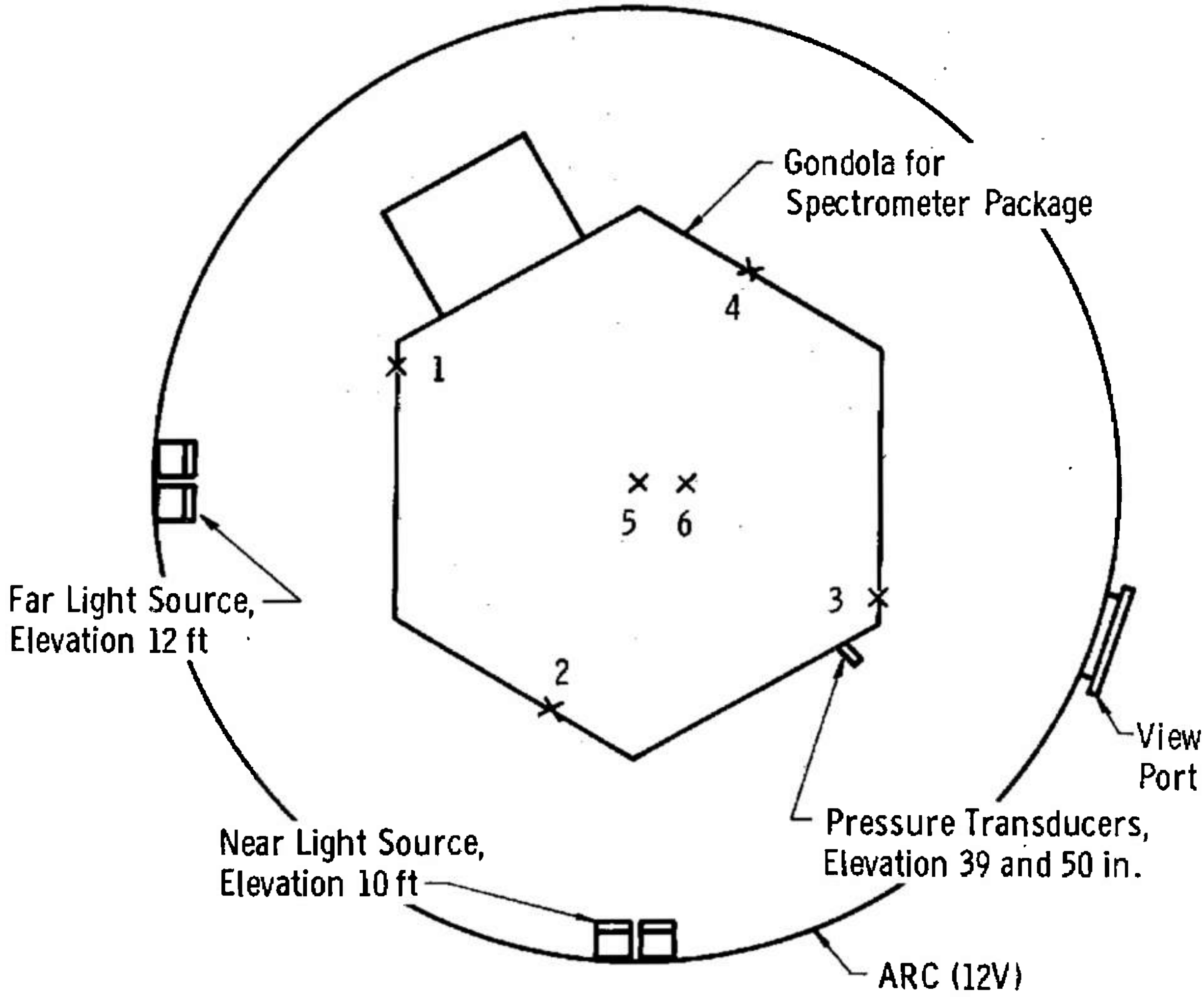


Fig. 5 Nitrogen Inbleed Schematic



Thermocouple	Elevation, in.
1, 2, 3, 4	23
5	73
6	6

Fig. 6 Test Schematic

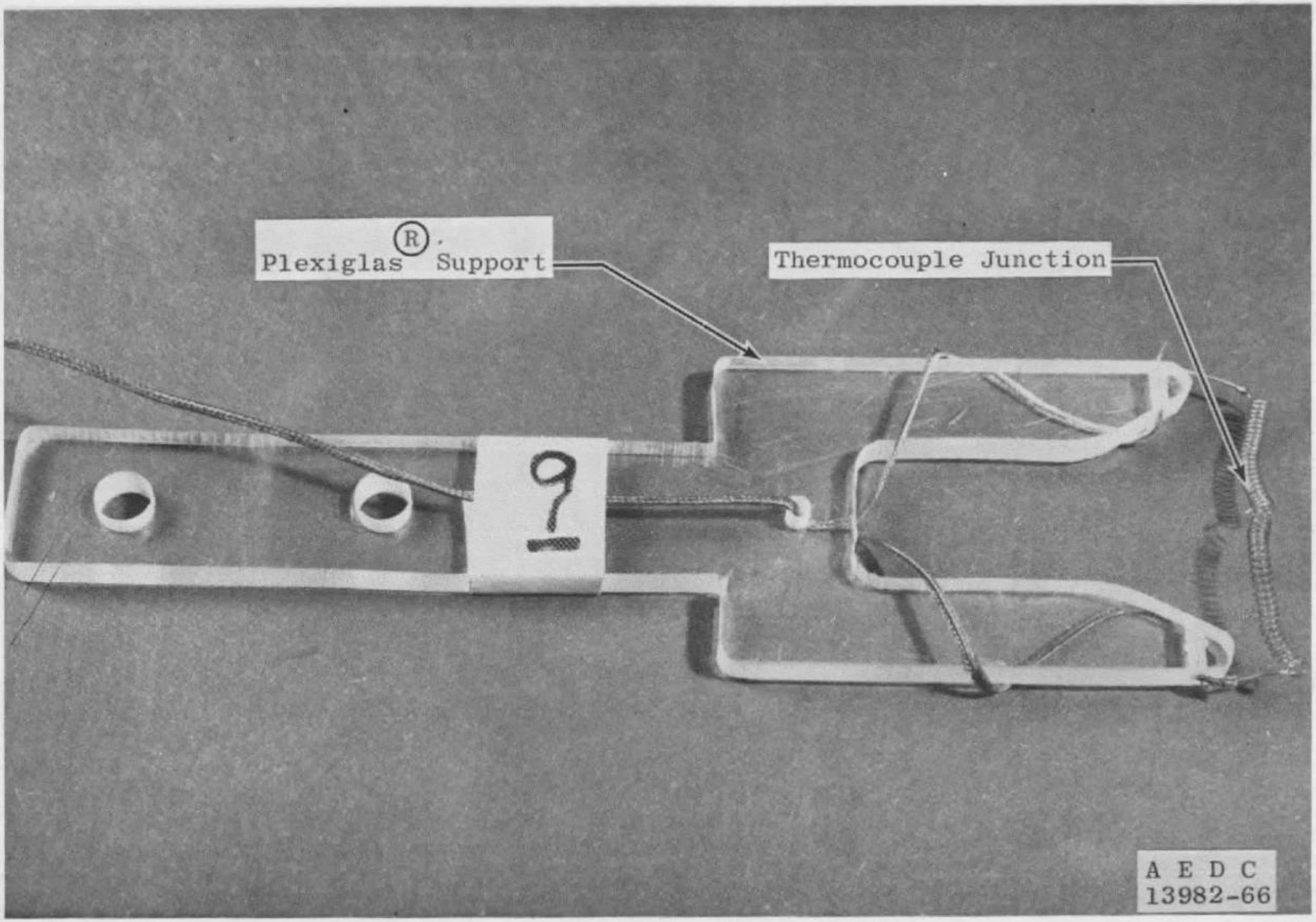


Fig. 7 Air Temperature Probe

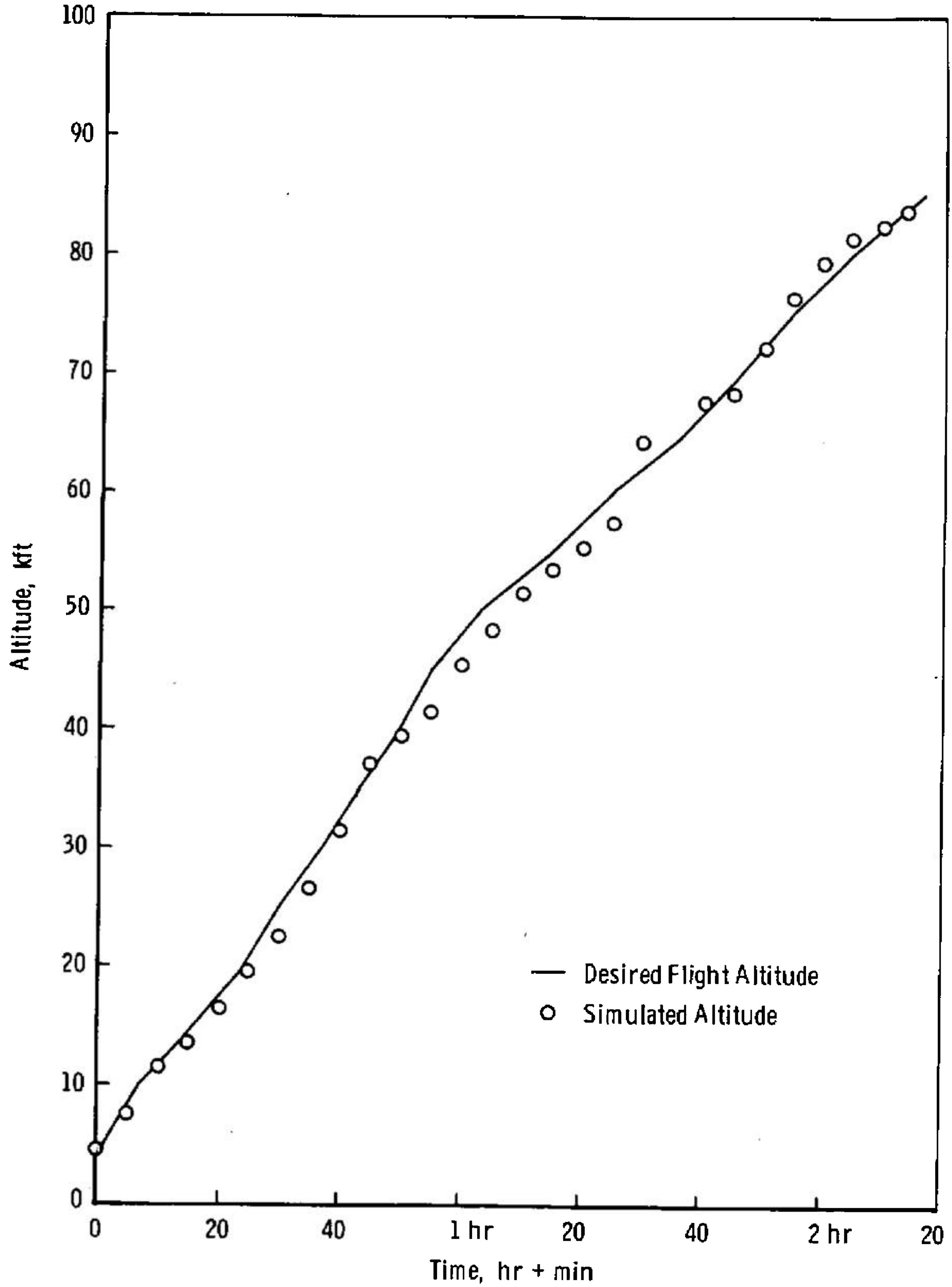


Fig. 8 Simulated Flight Test Altitude

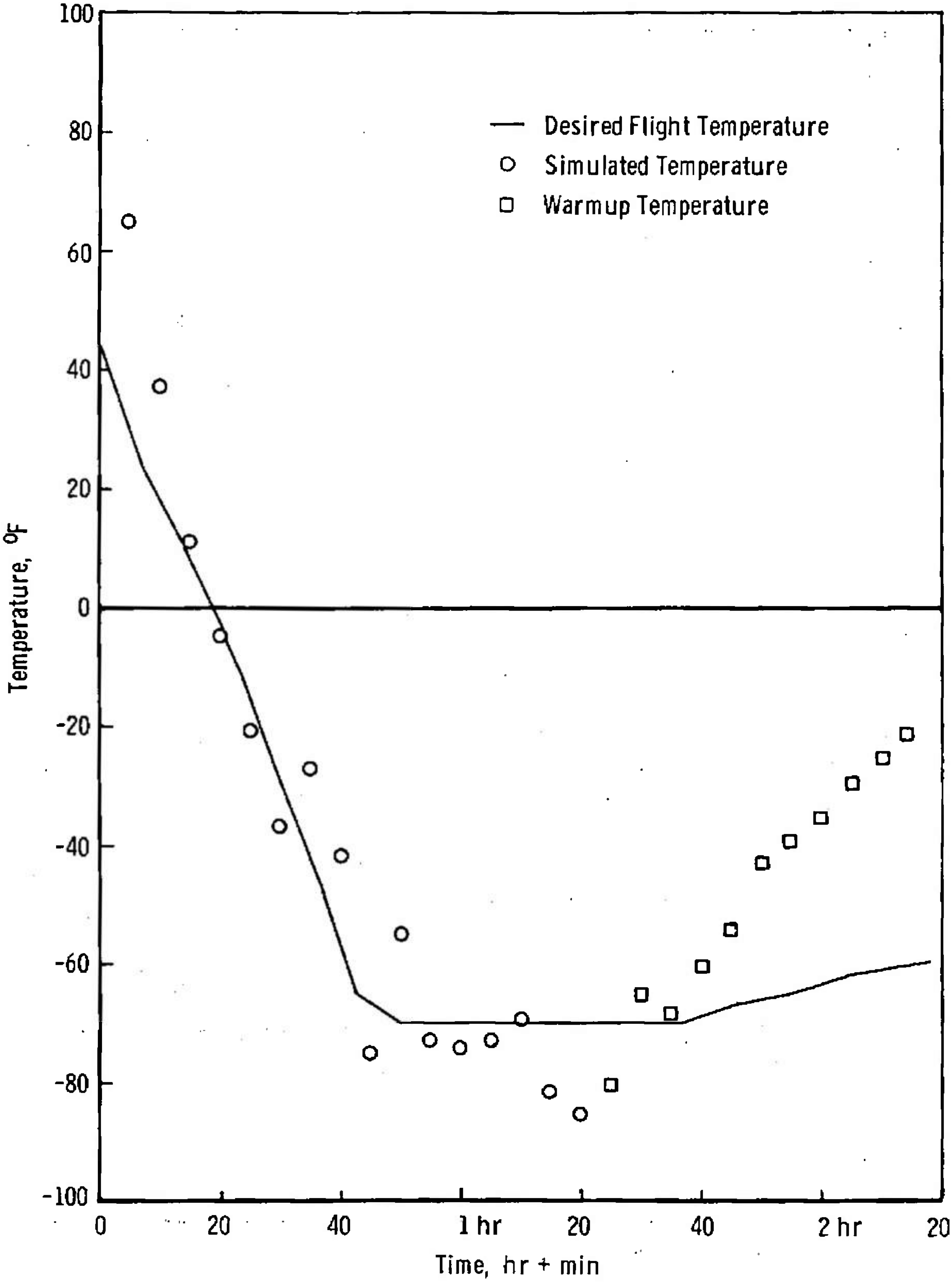


Fig. 9 Simulated Flight Test Temperature

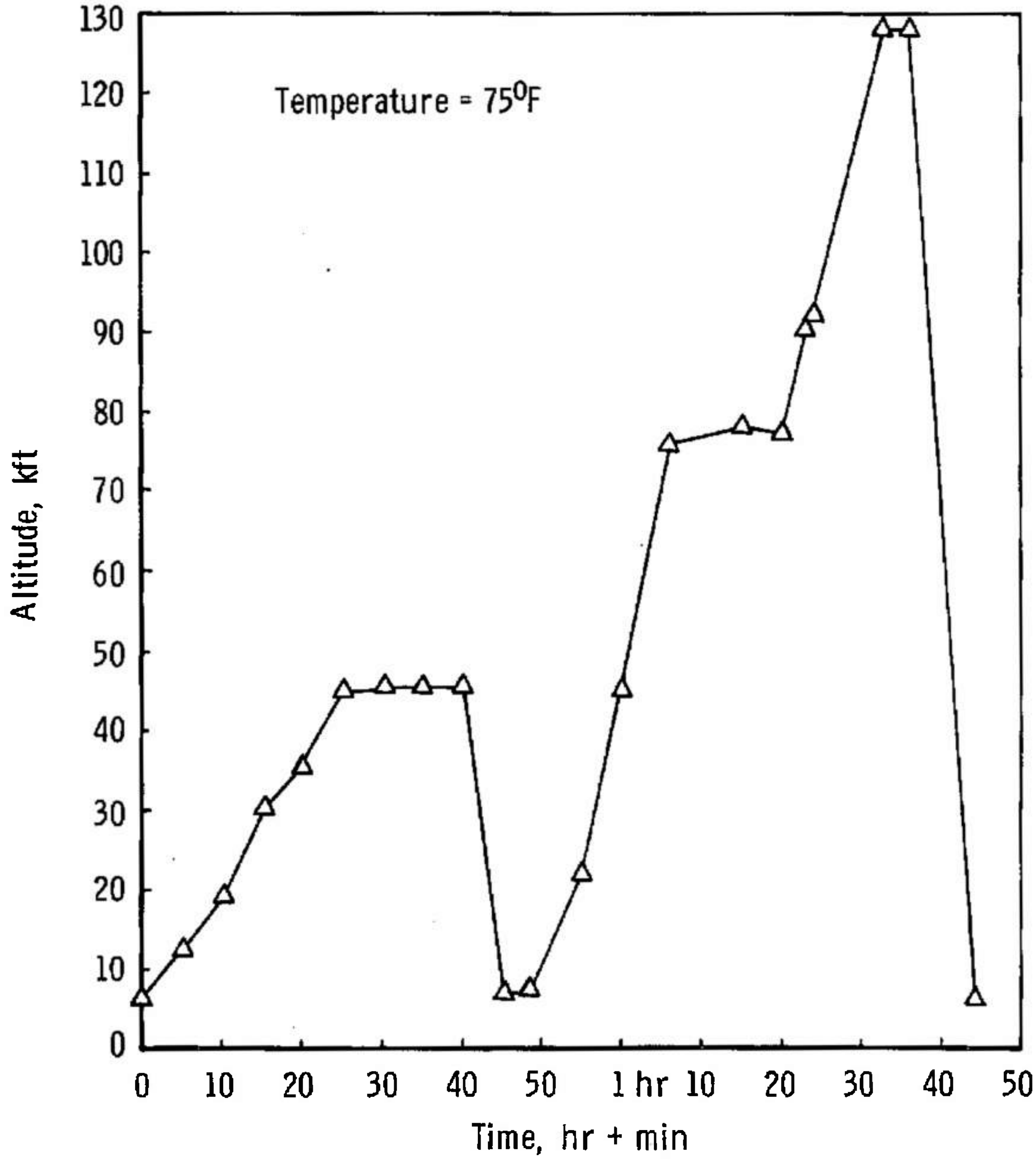


Fig. 10 Altitude Test

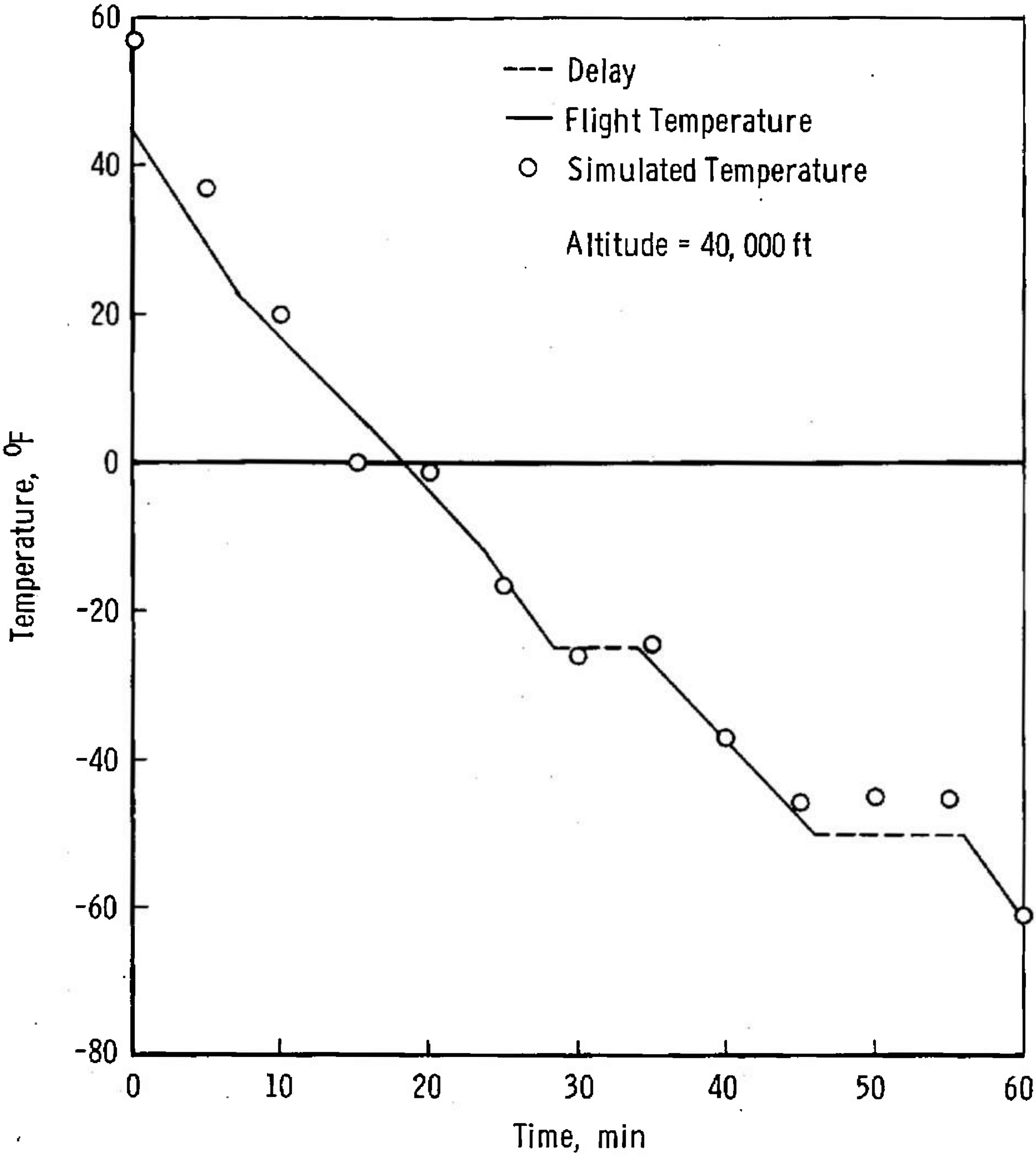


Fig. 11 Temperature Test

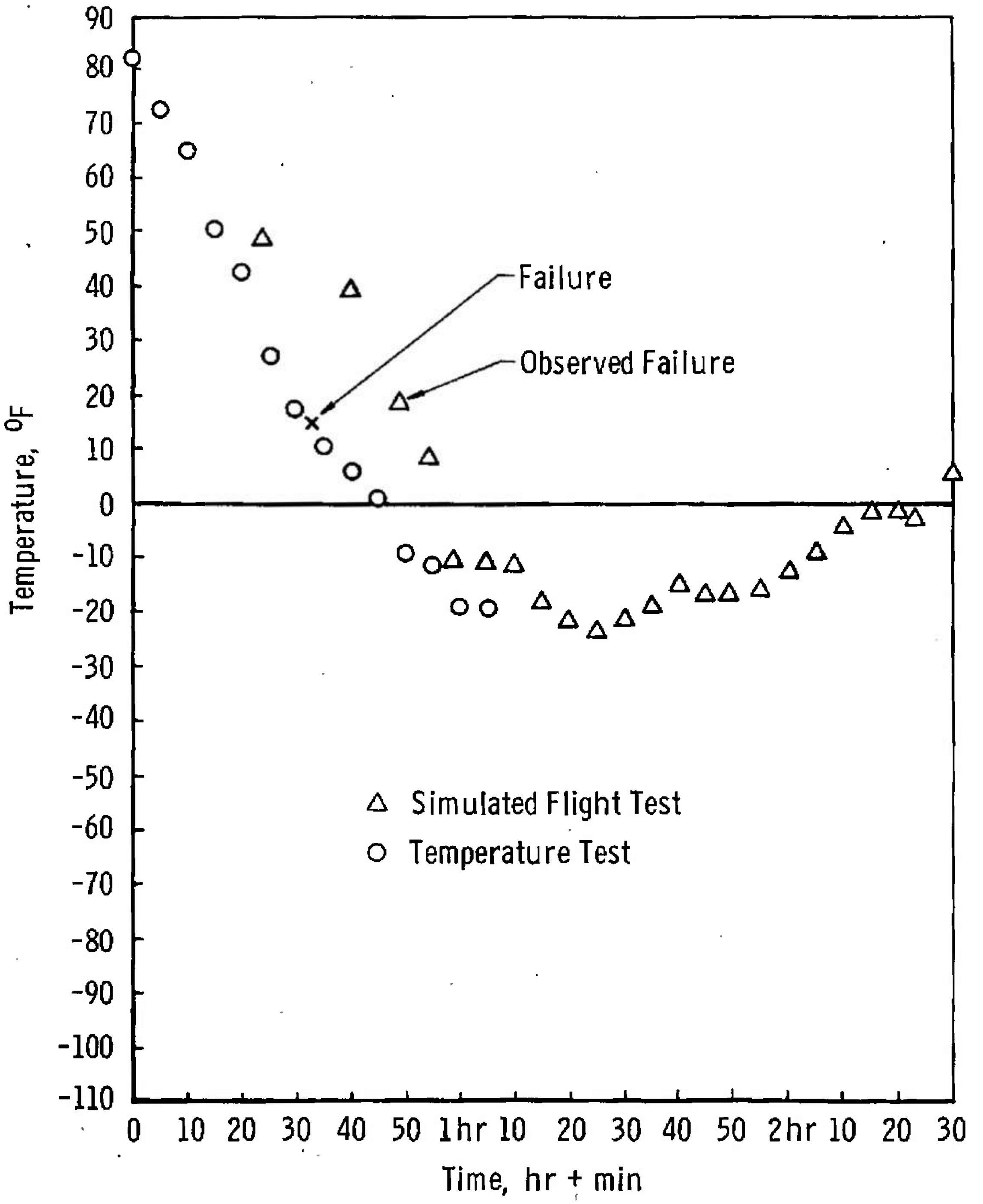


Fig. 12 Quarter-Wave Plate Drive Temperature

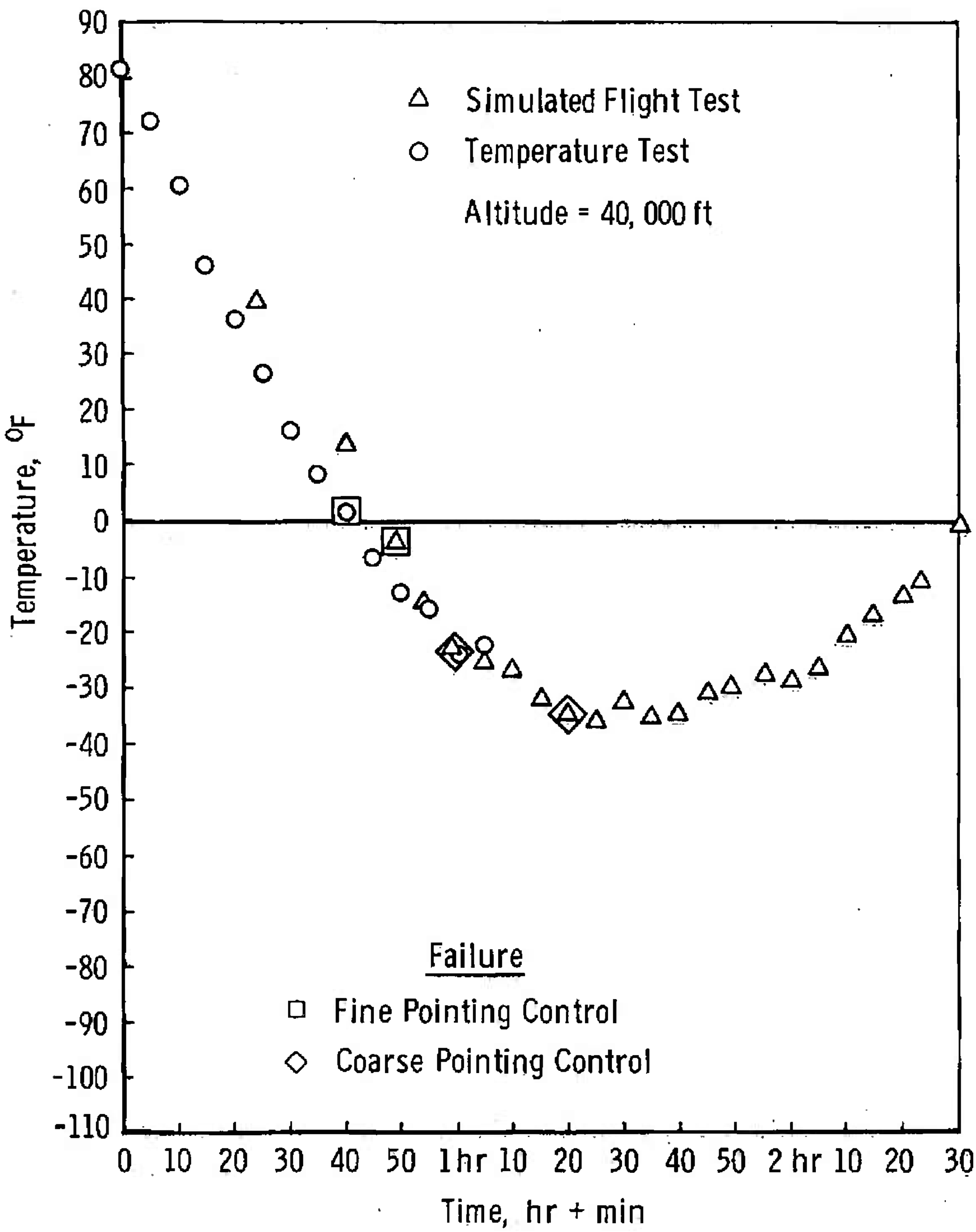


Fig. 13 Pointing Control Case Temperature

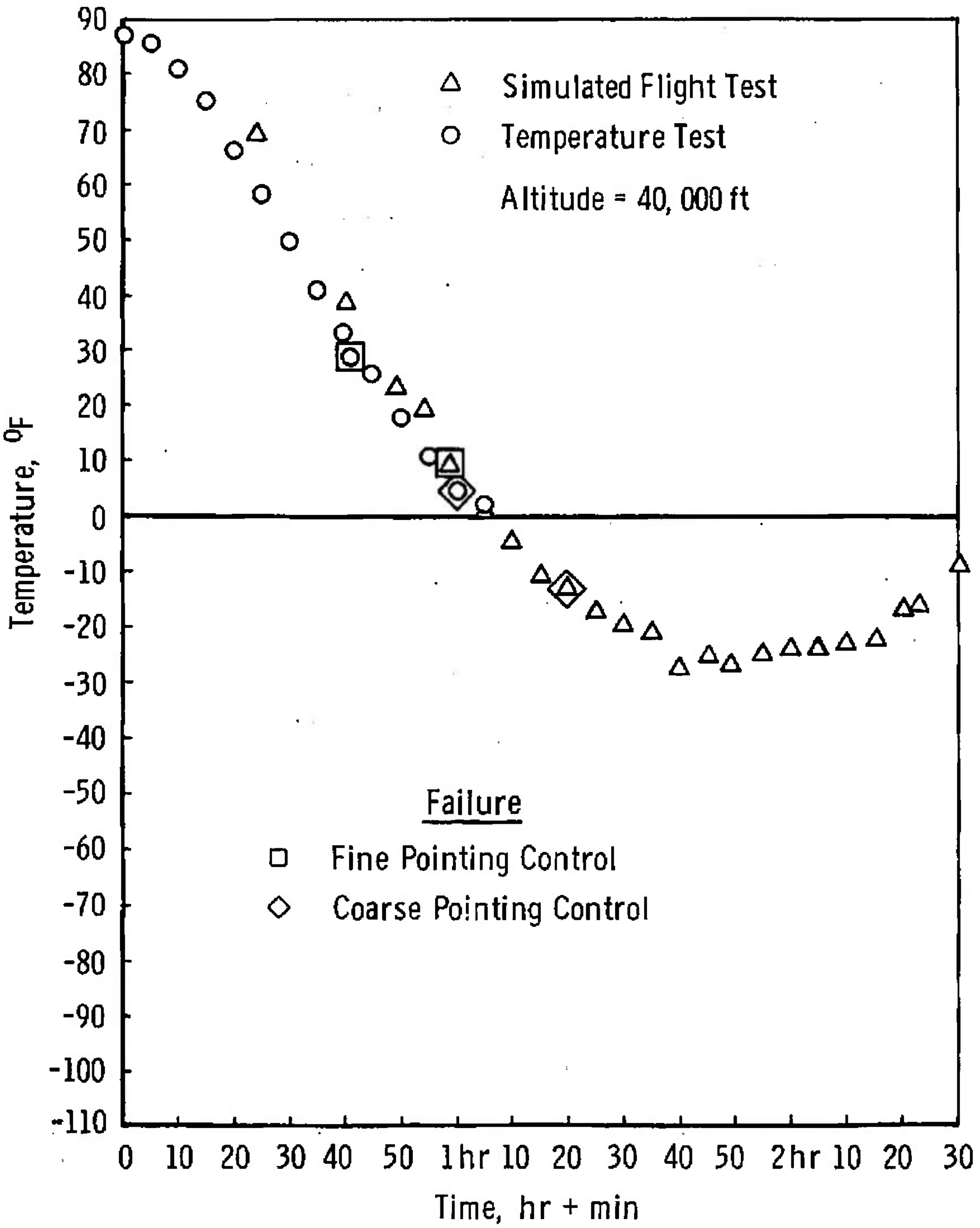


Fig. 14 Pointing Control Amplifier Input Stage Temperature

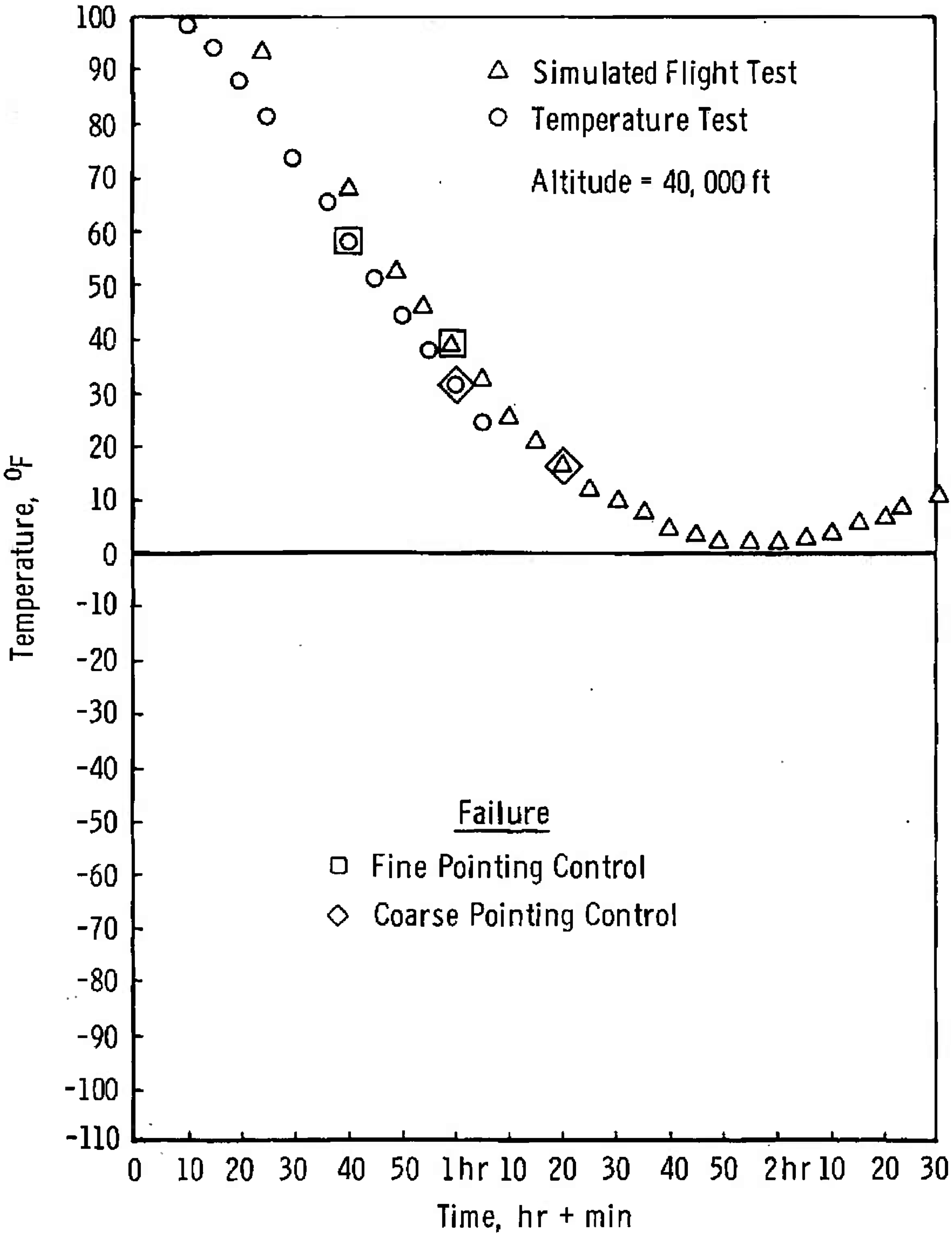


Fig. 15 Pointing Control Amplifier Output Stage Temperature

TABLE I
SPECTROMETER PACKAGE THERMOCOUPLE LOCATION

Thermocouple Number	Location
1	Spectrometer detector head side
2	Spectrometer detector head end
3	Sun shade
4	Guard cell sensors
5	Quarter-wave plate drive gear side
6	Quarter-wave plate drive motor side
7, 8, 9, 10	Spectrometer case
11	Spectrometer support yoke
12	Spectrometer support yoke containing gear train
13	Elevation servo
14, 15	Junction box
16	Azimuth servo gear box
17	Pointing control case
18, 20	Input stage of pointing control amplifiers
19, 21	Output stage of pointing control amplifiers
22	Commutator for telemetry in the control panel
23	Circuit board support in sequencer box
24	Ground plane

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1. ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center ARO, Inc., Operating Contractor Arnold Air Force Station, Tennessee	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE
SIMULATED BALLOON FLIGHT TEST OF AN ULTRAVIOLET SPECTROMETER SYSTEM

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
N/A

5. AUTHOR(S) (Last name, first name, initial)
Burch, B. A., ARO, Inc.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1966	30	2

8a. CONTRACT OR GRANT NO. AF 40(600)-1200 b. PROJECT NO. 7621 c. Program Element 62405394 d.	9a. ORIGINATOR'S REPORT NUMBER(S) AEDC-TR-66-163 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A

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N/A	AF Cambridge Research Laboratory Air Force Systems Command Hanscom Field, Bedford, Mass.

13. ABSTRACT

A balloon-borne spectrometer package was tested under simulated flight conditions of temperature and pressure within an environmental chamber to study the real-time pressure-temperature effects. Four components of the spectrometer package malfunctioned because of low temperature effects.

1. Balloon - flight simulation
2. Spectrometers
3. Ultraviolet spectrometer

17-5

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